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BOTANICAL GAZETTE

JANUARY 1899

ON THE VEGETATION OF TROPICAL AMERICA.¹

EUG. WARMING.

TWICE I have been able to visit tropical America. The first time was about thirty years ago, when as a young student I stayed for over three years in Brazil, almost the whole time in Lagoa Santa, with the paleontologist, Dr. P. W. Lund. The second time was in the winter of 1891-2, when I traveled for some months in the Antilles and Venezuela. Having been requested to deliver an address at one of the general meetings of naturalists I have thought that perhaps it would be of interest to those present to hear some statements about the vegetation of tropical America, and some attempts to explain its deviation from our own northern one. Most likely these statements will in some degree correspond with the facts about other tropical countries, but as it is best to keep to what we are in some degree acquainted with, I must say that where in the following I am speaking of tropical facts, it is especially the American ones that I have in mind.

The interest of the northern botanist newly arrived in the tropics is immediately awakened by the variety of species, genera, and even families of which he has never seen living representatives. Of course this is not peculiar to the tropics, for into whatever non-tropical or even alpine region he goes, he will find a wide difference from the vegetation of his native

¹An address before the Scandinavian Association of Naturalists, at the Copenhagen meeting.

country. But when he has viewed things somewhat closer, especially in the forests, it is the *multitude of species* and the *poverty of specimens* of every species that sets him wondering, and as these facts are characteristic of the tropical flora, I shall begin by speaking of them.

Every one has heard of that multitude of species. When wandering through a forest, and looking upward into the foliage, one finds the most different forms of leaves showing their outlines against the bright sky. Trees and bushes of the most different species are to be seen everywhere, but one seldom finds more than a single individual of the same species. If in search of more than one specimen of a certain species, one will very often have to seek a long time; and of certain species of forest trees near Lagoa Santa I was able to find but a single individual.

To my knowledge there is no botanist who has illustrated this curious tropical richness of species by numbers. I am fortunate in being able to give some numbers that seem to be rather elucidative. Through the three years in which I lived in Lagoa Santa, I constantly made botanical excursions; but since, on an extreme estimate, only six or seven hours of the day were entirely at my disposal—and just those hours in which the heat was at its height—and since I had to take nearly all my excursions afoot, the ground investigated was only about 150 square kilometers in extent. On this insignificant territory I have gathered more than 2600 vascular plants, besides some hundred lower plants, but as I have not found absolutely all the species, especially not all those of the forest, I certainly may assume that the place contains at least 3000 species of higher plants.²

One will understand the meaning of this number if he examines an equal area in the fertile parts of the northern countries, which will be found to contain only about one fourth part of the aforesaid number. If we take the whole of Denmark with its 38,300 square kilometers, we find only half of the given number; and if we take Sweden and Norway, with an approximate area of

² *Vide* my work "Lagoa Santa," in the Danish Videnskabernes Selskabs Skrifter VI. 6:—. 1892.

772,900 square kilometers, we find not even two-thirds as many species. Yet these countries have both forest and meadow, heath and shore, rocks and moorland; in short a much more varied vegetation than the 150 square kilometers around Lagoa Santa, that are almost entirely covered with campos and forest.

I may give some other numbers; for example, the number of specimens of trees, small and large. The forests around Lagoa Santa seem especially to follow the watercourses. In every valley runs a brook, or a creek, or a river, on its way to Rio des Velhas. The forests form a border of variable breadth to these streams. They advance up the rather rugged terrain until the hills become too dry for them and the vegetation of the campos conquers them. Suddenly, then, the forests are succeeded by campos, that unbrokenly cover all the tops of the hills and all elevated ridges. The predominant feature of the country is the campos, or what the Spaniards would call savannas; flowery grassland that, where the red clay soil is deep and rather free of stones, also bears scattered trees, and has the likeness of a park or a garden with fruit trees; for the trees of the campos have not the straight and high trunks that are peculiar to the trees of the forests. On the contrary, they are like our fruit trees, low, with crooked stems and branches, and broad, open crowns, through which the sun's rays unhindered reach the grassy ground beneath. It must be noticed that where the campos are most vigorous the trees are able to form groups that have almost the aspect of groves or small forests.

The campos and the forest vegetation are two quite different formations, both in a biological and in a floristic way. The species of the forest are quite different from those of the campos, with the exception of a very few. Do we not find a second proof of the curious richness of species in the tropics in the fact that in the campos of Lagoa Santa not less than ninety species are to be found, and in the forest about four hundred? Of course the trees are growing intermixed. Several times I had an excellent opportunity for studying the composition of the forests. When a Brazilian farmer lays out a plantation, he cuts down a piece of

forest at the beginning of the dry season, and the burning sun having for some months heated through and dried the mass of felled trees, bushes, creepers, herbs, and the crowd of epiphytes that lived in the forest, he burns up everything, and in the ground now fertilized with the ashes and afterward cleared and leveled, he sows and plants.

One can imagine the botanist's joy. Those trees, at whose crowns and flowers he had gazed so often without being able to reach them, lie now, by such a "Derrubada," outstretched at his feet. In six different cases I have estimated the proportionate numbers of the species and individuals, and I have found that among 50-250 trees there were 27-91 species; that is, every species was represented on the average by two or three individuals. To us of the north, accustomed to the uniform forests of beeches, spruces, firs, etc., there is something most strange and overwhelming in such a variety of forms.

As in the trees, so in the other parts of the vegetation, the herbs and shrubs. The same thing is also true in the animal kingdom. Wallace says that more than 700 species of butterflies live near Para, on the Amazon, while all Germany has but 150, and England only 64 species.

Now the question arises: What is the cause of this multitude of species in tropical nature? It seems obvious that these hundreds of trees, to speak only of them, living together in a forest of such small extent as this one near Lagoa Santa, must be similarly equipped in a physiological way, so that one species is not able to overcome and supplant another in the manner we know the beech, with us, is supplanting the oak. Every one of these tropical forest trees must shade as much, and at the same time be as well suited with the shade, as the others; that is, they are alike in fighting condition. In short, they must stand in quite the same relation to one another as the single individuals of the very same species; that is, just as the beech trees are interrelated. But how they have been able to reach this adaptation is a very difficult question, of which an explanation is at present an impossibility. Nevertheless, there is *one* condition that no

doubt has played a conspicuous part in the process; I mean the history of evolution of tropical nature.

All characteristics of a vegetation may be classified into two groups of factors, *historical* and *physical*. All alterations that the climate, the ground, and the surface of a country are passing through from time to time must express themselves in the vegetable world up to this very day. Consequently this is the case with the inner highland of Brazil where Lagoa Santa is situated.

In the first place, Brazil is a primeval country, Geikie's map³ showing us that even in paleozoic time, when the firstlings of life appeared on the earth, the highlands of Brazil and Guiana were raised above the sea level, while the other parts of the future South America were still in the keeping of the sea. In subsequent geological periods the area of land grew larger. The red clay that forms the surface of large parts of the soil is a decomposition product of the primitive rock. Also the lime rocks, that stick out through the clay here and there in Rio des Velhas valley, and in which P. W. Lund's celebrated caves with their fossil remains of extinct species of animals are found, are of a primeval limestone without vestiges of fossils.

Secondly, this highland has, so far as we know, been favored by the most excellent tropical climate. Though the ice on the highest of South American mountains is said to have been far more extensive formerly than now, no glacial period is known to have spread its life-killing mantle over the highland of Brazil. Then the vegetation developed itself undisturbed through geological periods. The species of plants have differentiated, fought out their conflicts, accommodated themselves to one another, and blended with one another. The vegetation has thus had plenty of time, and only when we take this fact into consideration shall we get nearer to an understanding of the present variety of species.

How widely different, for instance, are the facts in northern Europe! Here we have to do with a comparatively young

³ Proceedings of the Royal Physical Society of Edinburgh 10.

vegetation. Geologically speaking, only a short time ago the glacial period made a clean sweep over wide areas, and decimated the vegetation of neighboring regions, so that when it was at an end nature had to begin planting the ground anew. This surely is one of the causes of the poverty of species here in the north. Most likely other causes of a physical nature also exist. So far as I can see, the vegetation here in Scandinavia and even in the higher north might really have been much more rich in species than now is the fact; *only it has had no time* for that, but for every century or, better, millenium that passes, other species, even without the help of man, will immigrate and mix themselves with the old ones, and new species will arise.

Of course this variety, which is one of the characteristics of tropical nature, also shows itself through *that immense mass of curious ecological adaptations* which we know or eagerly try to discover. There is a great difference between the objects of botanical exploration during the first five or six decades of this century, and those of the later decades. It was Darwin's monumental work that led science into new ways. Formerly the botanists especially wished to discover the many unknown genera and species. Now it is *life* itself they wish to study, those wonderful relations of the varied and often very complicated reciprocity of action between living beings, of which a great deal is already known, such as mimicry, the fecundation of plants by insects, the adaptation of epiphytes and other plants to surrounding nature, ant-loving plants, insectivorous plants, parasitism, and other ecological facts. These are mostly to be looked upon as directly and entirely independent of climate and other physical conditions, while the number of them will hardly be understood, unless, as Wallace has done, we take into consideration the probably uninterrupted process of development of tropical nature through geological periods.

Now we must acknowledge that within the tropics the richness of forms is different in different situations. Even the small Lagoa Santa shows a striking example of this, for the forest is twice as rich in species as are the campos, although the area of

forest is much smaller than the area of campos. The relative number of species is about 1600 belonging to the forest, and 800 to the campos. The forest also is much richer in families and genera. Of the 149 families of vascular plants living on the whole area no less than thirty-seven are peculiar to the forest, while but two are peculiar to the campos, and, moreover, each of those two is represented by but one species. Further, of all the genera (about 750) 364 are to be found only in the forest, while only eighty-two are peculiar to the campos.

Here, again, we meet the question, why this difference? In this case I suppose physical conditions to be the causes, although historical facts possibly may be of importance. To be able to understand this evolution of species it is necessary to know whether the campos flora was the primeval one on the old Brazilian highland; or whether from the first the forest covered the country and, later on, forced by physical alterations, retired from the higher and drier parts of the country, where the campos arose, beginning with forest species that adapted themselves to the new conditions. About this, however, I am not able to say anything; we only know that for endless times there must have existed open and woodless land in the interior of Brazil, seeing that Lund has found here remains of now extinct species of the horse and llama types; that is, remains of animals that could only live in a woodless country. I myself feel inclined to suppose that the forest vegetation is the primary one, and for that reason also the richest, while the campos vegetation is the younger one; for most likely the moisture of the climate was much greater when only the inner highland was above the sea, and as the country grew larger in every direction the climate gradually grew drier and drier.

Between the forest and the campos vegetation there seems to have been, in a physical way, originally but one difference, namely, the unequal moisture in the soil. For the soil in which the two different vegetations live is in origin and composition evidently all one, namely, the before mentioned red clay, a product of the decomposition of the primeval rock. But in the valleys, where

the forest reigns, the soil is richer in water, and it is my opinion that the water after all is the most essential cause of the distribution of plants, the physiognomy of the vegetation, and the ecological stamp of the vegetation formations. It has been very much disputed whether it is the chemical or the physical qualities of the soil that are the principal causes for the distribution of plants; as to the vegetation formations it is my opinion that we find the principal cause in the quantity of water the soil is able to receive and keep, no matter whether this is owing to physical or chemical causes. Difference in richness in water was the condition for the occurrence of these two formations, but in the course of time the forests improved the soil by their own work, constantly accumulating more or less of humus. In the campos, on the contrary, the sun desiccates the fallen leaves, which crumble into dust and disappear. One thing more; the forest gives shade to a good many species that are not able to endure intense light. Hence the forest affords physical conditions for a vegetation that is not to be found in the campos, and most likely this is the essential cause of the great richness of the forests in species. Favorable conditions of vegetation seem also to entitle one to suppose a more profuse origination of species.

If we compare the Brazilian campos with similar regions in another part of South America, the Venezuela savannas, which seem to possess the very same physical conditions and where a corresponding vegetation has developed itself, I believe we shall learn to some degree the importance of *historical* facts. A few months ago I traveled in Venezuela. At the sight of the savannas I was overcome with the greatest surprise and even joy. Never should I have expected to find such a striking conformity with the Brazil campos. I felt as if I were removed to the campos near Lagoa Santa, thirty degrees of latitude south of Venezuela, and there arose in my memory the happiest years of my youth.

When one is traveling from Puerto Cabello through the country to Valenzia, and has reached the high passes of the

coast mountains, the continuous forests suddenly cease, and one has a wide view over a woodless country, partly plains, partly mountains, whose jagged outlines and water furrowed faces stand out sharply in the sunbright air. Far to the south behind the lake of Valenzia, one may see other blue looking mountains, and behind those lie the Llanos. In Brazil one meets quite the same experience. When one has traveled through that much broader border of forest-clad mountains which rim the Brazilian coast, and from the heights of Serra da Mantigueira looks down over the campos country, one sees the clouds cross the coast range of mountains, roll part way down the western slopes, and dwindle away in the dry air of the sunny campos ; just as in Venezuela the clouds pass over the Caraibic mountains and disappear where the dry savanna country begins. The soil seems to be like the Brazilian ; it was the same red clay, or at all events much like it, and here and there rich in sharp-edged gravel. There was on it the same carpet of high grayish grasses and other herbs, and here and there the same stunted trees, with the same coarse leaves, and even with trunks blackened by savanna fires, just as around Lagoa Santa ; it was the very same form of vegetation and even to some degree with the same species as in Brazil. Only one thing I found different, the quantity of species. Those savannas evidently were *much poorer* than the campos of Lagoa Santa. Only a few species of trees were found here on an area which at Lagoa Santa would have been in possession of six to eight times as many. I must admit that it was a rather short visit I could pay those savannas, but my impression is quite in accordance with the experience of other travelers in the Llanos and other parts of Venezuela, for instance the valley of Caracas. This tract, with its 125 square kilometers, contains, according to Ernst, 104 species, and he considers the flora of Llanos as a degenerate offspring from that of the surrounding countries, without endemic genera. As in all essentials the physical conditions of the campos and the savannas seem to be identical, the cause of the poverty of the latter surely is a historical one, and most likely the following.

In the Tertiary period an ocean rolled its waves over these plains that are now covered by the savannas of Llanos and the forests of the Orinoco and the Amazon. When at last the bottom of the ocean got above the sea level, plants from the surrounding highland immigrated, and the resulting vegetation got its stamp from the physical conditions. Where the ground all the year round was moist and the rainfall abundant arose the dense forests and marshy land along the Orinoco and other rivers; and where the ground was dry, at all events periodically, the savannas resulted. In the forests and on the marshland the number of species certainly is very large on account of the extraordinarily favorable physical conditions of the place, while in the savannas, on account of the dryness, the development of species has been much slower. If then we compare the savannas with the campos of Brazil, the main cause of the difference in richness, the existence of which I must suppose to be real, seems to spring only from the difference pointed out in the age of the two vegetations. On the highland of Brazil, vegetation surely has existed as early as any plants existed on earth, but on the savannas of Venezuela they first arrived after the Tertiary period. Here in the north of Europe it is the glacial period, in Venezuela it is the late uplift of the earth's crust that is the cause of the comparative poverty of species.

Thus we see how both physical and historical factors may act in many ways upon the flora of different parts of the world and imprint upon them a different character in respect to the richness of species. It is not at all easy to determine the respective influence of the two groups of factors; only we may suppose that as to the richness of species the *historical* ones are the most important. Now I should like, as far as in this short hour it is possible, to instance how *physical* facts act upon the tropical vegetation, and give it another look than that of our northern one. For that purpose I shall speak briefly of the three vegetation formations already mentioned, and most general of all: the *forest*, the *scrub*, and the *savanna*; but before I do so, I shall remind you of the physical factors, *light* and *heat*, both of

which in my opinion are of prime importance for the physiognomy of vegetation.

As to the *light*, I shall remind you of the fact, that only in the light the plant becomes green, and only by aid of it and of green coloring-matter—the chlorophyll—can organic matter be formed. Without light and chlorophyll no organic matter would come into existence. Thus in the household of nature the importance of light and chlorophyll is enormous. But on the other hand chlorophyll may be destroyed by light, and the destructive action may be greater than the constructive. Certainly for every species of plant an optimum light exists; if this be exceeded, many, perhaps all, green plants are in possession of one or another means by which they protect themselves against too intense light.

Closely connected with the light is transpiration, which is dependent not only on the heat and moisture of the air, together with several other factors, among them those internal to the plant itself, but even upon the intensity of light, since the light is converted into heat. By a too profuse transpiration the plant wilts. Against this the plant must have means of defense, and these are partly the same as those that protect against too intense light.

As before mentioned, the water in the soil is of prime importance for building up the plant and for the production of different types of vegetation, and for their distribution in the landscape.

Taking into consideration these facts, besides the high degrees of heat and the intense light of the tropics, we may easily understand the differences of the tropical plants from those of our northern climates. Against too intense light and too profuse transpiration the tropical plants have to struggle, and that struggle imprints its stamp upon them. As in physical respects there are only differences of degree, not of kind, between the two regions we are comparing, it is but natural that the plants in their structure also show only differences of degree. The same characteristic structures we find in the tropical vege-

tation we may also find in our own northern one, only they are here much more faint and rare.

The first vegetation formation I wish to speak of is the *forest*. The uniformity of climate in respect to the moisture, especially of the soil, gives to the forest its stamp.

At a distance the tropical forests are like our own northern forests of foliiferous trees, possessing the same mellow and rounded outlines, but the *foliage is differently colored*, which seems only natural in consequence of the many different species. Further, the trees are all of a much darker hue than those of ours; at all events, I have never seen a tropical forest with those fresh, bright green colors, that we love and admire in our own birch and beech woods in spring. This difference in coloring is easily understood. The everlasting summer of the tropics and the unceasing development of tropical nature have been very often spoken and written about. Bates says: "There is neither spring, nor summer, nor autumn, but every day is a combination of them all." Really he is partly right. To be sure, the stamp of death or sleep impressed upon our woods of foliiferous trees by the winter is unknown in the tropics, where the trees, on account of the uniformity of the climate, are mostly evergreen (except a very few), as are our coniferous trees and also many of our small brushes and herbs even in Greenland. But we must not believe that life and development are of the very same intensity all the year round, so that every species of tree is getting new leaves, flowers, and fruits at all times of the year. With exception of a very few herbs, such an unceasing process of development is, according to my experience, not to be found anywhere. Near Lagoa Santa, at all events, every species has its time of rest, and at distinct times for the different phases of life. There is plainly a time of spring, namely, from August to October, and there is plainly a winter time; there is a settled leafing and a settled fall of the leaf; but in this the tropical forest shows a great deviation from our woods of foliiferous trees. Our foliiferous trees unfold their leaves in May and lose them in October; nearly six months the leaves

remain on the trees. But how long time a tree will keep its leaves depends partly upon the physical conditions, hence the same species in other conditions more favorable for the life of plants may keep its leaves longer. In the tropical forests, with their uniform physical conditions, the leaves may live much longer, though most of them are not able to live for more than one year, and only a few may remain for two years. They do not fall before new leaves have appeared, but none of them is able to reach the age of the acicular leaves of our pine trees. This long duration of the old leaves causes the almost unaltered dark hues of the tropical forest.

During my last journey in the tropics one of the characteristics of the forest trees that attracted my attention was the frequency of highly glistening leaves. Everyone knows the glistening leaves of the rubber tree, *Ficus elastica*, and of our own Christ's thorn, *Ilex Aquifolium*, and in some smaller degree of other trees, though most generally the leaves of our trees are dull green. In the tropics the gloss of the leaves is much more marked; everywhere one may see the dark green leaves reflect the light, and even such plants as the cocoa tree, the plantain, the Indian corn, and the sugar cane have something of that gloss which is especially associated with the dark green, stiff, and leathery, long-lived leaf. Of course, this gloss depends upon certain anatomical structures, and it seems to be, directly or indirectly, a defense against too intense light.

Another fact that gives the tropical forest an aspect different from that of our own forests of foliiferous trees is the large, bright spots of yellow, white, red, purple, and other tints that from time to time are to be seen here and there, when one or another of the woody plants or climbers is in blooming and covers itself with flowers out of number. This phenomenon shows us both the sparseness of the individuals and to what degree the flowering of every species is fixed to a certain time of the year. It is said that almost all species are flowering all the year round, but this is unquestionably an error. An explanation of this misstatement we find in the fact that different species have a differ-

ent flowering time, some of them even blooming in the winter, that is, in the dry season, and in consequence we may find flowers at almost all times of the year. In Lagoa Santa grows a water lily, *Nymphaea Amazonum*, and if any plant could be expected to show continuous growth such a one in a tropical lake should do so, even though it were an annual, which it hardly is. But at the beginning of the dry season this plant disappears from the surface of the lake, and not until the rainy season has come, in October, do the leaves and afterward the flowers appear anew. The very same fact, though not so distinctly, we find in the case of other water plants that are decidedly perennial.

The *second* type of vegetation I wish to speak of I have seen in Venezuela and in the Danish West Indian islands; it is the dry bushes or *scrub*. Hardly any vegetation can be more disagreeable and ugly than this scrub of brambles and thorns. Thorny cactus and agave plants, with grayish and brownish hairy leaves, that in the dry season partly fall; everywhere a baking heat and dryness, in some places an immense number of gnats; such is, in short, this scrub which we in northern regions never saw the like of; only in the Mediterranean countries, in the so-called Maquis, do we find anything similar.

In a most striking manner the scrub shows us how the physiognomy of the vegetation depends upon physical conditions. These bushes have to defend themselves against too intense *drought, heat, and light*. The outer and inner construction of every species bears an impress of that. The grayish hairy coverings, especially remarkable in the species of Croton, that give the whole landscape such an ugly appearance, are, in the first place, an excellent defense against transpiration, and this defense may be further strengthened by the rolling up of the leaves. On many Croton bushes I saw how all the leaves that were in shade were flattened, while those that were exposed to the direct sunlight had in different degrees rolled themselves up, so that the under side, which is the more hairy one, curved outward. This defense against drought is not quite unknown to us, only we have to seek it among plants that live upon dry,

sandy fields, in the downs, upon the heaths, and in similar localities, which at periods are hot and dried up.

Also in the forests of the tropics one finds these grayish hairy leaves especially on lianas, I believe. Among these plants a xerophilous construction is not uncommon, and why this is the case is easy to understand; for their stems are often many meters in length, with a diameter of a few centimeters; they ascend to the tops of the highest trees, clambering from one to another, and one may see them hanging like long festoons between the trees. Through their slender stems the water is to be lifted from one single root up to the leaves; it has, therefore, an exceptionally long way to travel, and though nature has tried to provide for this by making the vessels of the stems, that is the water-conduit pipes, wider than in any other plants, it is easy to understand that it is, nevertheless, not without benefit to the plant to be able to moderate the transpiration.

In many lianas, as well as in other plants, both in the forest and in the scrub, one finds another peculiarity also that is not unknown in our northern vegetation, but is much more frequent in the tropics, that is, the latex. When cutting through a tropical scrub every moment one will have an opportunity of seeing the latex dripping in large white drops from the wounded stems. We do not yet understand the importance of latex in the life of plants; different hypotheses have been presented, but none generally accepted. Most likely the latex serves several purposes, and one of them, I suppose, is to supply water to the leaves in times of need, when the transpiration becomes too profuse. If the latex tubes really have this task, looking upon them from an anatomical standpoint, we must admit that their structure is exceedingly suitable to the purpose.

The scrub also shows other remarkable examples of defense against too intense light and profuse transpiration. However, I shall mention only one. While wandering in the scrub my attention was attracted by the difference between the numerous thorny acacia bushes and the other plants. The acacias did not have the leathery, dark green, glossy leaves peculiar to so many forest

plants; neither were they gray-felted nor furnished with latex; but in the middle of the dry bush so heated by the sun the plants stood with their strange lusterless, dull green and moreover extremely delicate and finely compound leaves. It was not difficult to discover that they had another defense, and one developed even to perfection against the intense light and transpiration; I refer to the photometric leaves that by an exceeding sensitivity for the optimum of light adjust themselves readily to the different amounts. In the gentle morning light the leaflets are extended flat, intercepting as many of the rays as possible. But later in the day, when the sun is rising higher and the heat is growing more intense, the leaflets fold themselves more and more together and upwards like a closing book, the consequence of which is that the light strikes the plane of the leaf at acute angles, by which its effect becomes weakened. Thus the leaf itself regulates the light and the transpiration, and the different aspect of the acacia bushes at different times of the day is not quite without influence upon the physiognomy of the landscape.

This phenomenon, as well as others, we find also in our northern climate; for instance, one finds the leaflets of the wood sorrel, *Oxalis Acetosella* in our forests differently placed with respect to the different light of the day.

The *third* type of vegetation I want to speak of is the *campos* or *savannas* already mentioned. To find anything like them one would have to go to the grass steppes of southeastern Europe. Trying to compare the savannas with our own grass fields and meadows, one finds a great difference in physiognomy as well as in ecology. The savannas have a dry or, at all events, at periods a dried up and hot soil; their grasses are coarse and stiff, grayish and hairy, and only fresh green in their first and short youth. And even admitting that the campos of Brazil especially are much richer in flowers than are our meadows, and that the flowers of the campos are much larger and with more gaudy colors than ours, I must say that the wonderful freshness and charm so peculiar to our green, luxuriant, thick, and soft meadows and

grasslands I have never seen anywhere, with the exception of a very brief time in the early spring.

The same is true in reference to the vegetation of the forest ground. Nowhere have I seen such soft, swelling, and fresh green moss carpets as those in our woods of coniferous trees, and nowhere have I seen such a flowering woodland as that of our beech woods in the early spring. The fact is that wherever in the tropics the rainfall is small and the ground dry, the vegetation develops itself either as savannas, or as dry thorny cheerless scrub, or as dry forests poor in mold, though rich in lianas, bushes, and small trees, because of which they are almost impenetrable; or the country becomes, as in the highland of Mexico, almost a desert. But if water is at hand, especially water in the soil, there all sorts of trees, bushes, and herbs will spring up luxuriantly, in an abundance and with a foliage unknown in the north. In consequence of the abundance of water either a forest or a marsh vegetation develops itself. If the soil is especially rich in water, there will be a marsh, with high grassy plants and other herbs, bushes, and even trees, a vegetation through which it is anything but easy and agreeable to walk, and where, moreover, malarial fevers abide. But if the moisture of the soil suits a forest, one with impenetrable masses of trees, bushes, and lianas will be formed. In the dim light of the forest floor, which is covered with leaves and dead branches, mosses grow only with difficulty. On the stems of the trees they struggle with ferns, orchids, and other epiphytes as to which shall keep the place, and they are even forced to migrate to the leaves; but thick, soft, green moss carpets are never found.

Now, with your permission, I shall conclude these descriptions. I have wished to throw into relief at once how historical as well as physical factors enter into and are determining the nature of vegetation in a country, and how, in my view, the *historical* factors are of importance as to the richness in species, while the physical factors are especially important in determining the physiognomy of the species and of the vegetation as a whole. And at the same time, I have desired to draw forth

some of the differences between tropical and northern vegetation. I shall sum up my apprehension of tropical nature in the words that Linné is said to have expressed on *Homo sapiens*: "Habitat inter tropicos, hospitatur extra tropicos." Perhaps this saying may be called a true one, remembering that the cradle of mankind most likely was in the rich and luxuriant tropical nature ; but I hold it for certain that outside the tropics man is not a transient guest. For, admitting the tropics to be ever so rich in species, types, flowery pride, and fragrance, and admitting it to be ever so easy for man to procure maintenance of life in this rich nature (and surely it is this Linné has had in view), we must say that outside the tropics, in our temperate climates, man has found his most charming *home*, and just here he develops himself supremely in intelligence, morality, and strength of character.

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